How to Establish Erosion Tolerances

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The premise that a certain level of soil erosion control is a desirable goal for individuals and for society has generally been accepted. However, there is not general agreement on the precise level of soil loss regarded as tolerable. Because rates of erosion that do not jeopardize soil productivity may vary greatly for different soils, the imposition of fixed soil-loss limits applicable to all soils alike appears unreasonable. This article offers a well-defined procedure for establishing practical erosion tolerance standards for any soil.

PROGRESS has been made in calculating erosion rates for many soils under a wide variety of climatic conditions (*1, 3*). These calculations indicate that conservation measures reduce erosion but seldom eliminate it entirely. Thus, there arises the problem of deciding how much erosion is permissible or tolerable.

It is impossible to answer all questions about erosion tolerances, but standards based on the best available information and judgment should be useful if established by reasonable and well-defined procedures.

As suggested previously by Stamey and Smith (*4*), the first procedural step in establishing an erosion tolerance standard is to choose a point, p, on the landscape. It is understood that soil properties at p are known or will be determined, at least within bounds.

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Next, certain definitions and assumptions are made:

1 Erosion tolerance must provide, by definition, for the permanent maintenance or improvement of the soil as a resource.

2 Erosion tolerance must take into account the erosion (wearing away) and the renewal (adding to) of any soil property, their difference being the net rate of change.

3 Erosion tolerance must apply regardless of the cause of erosion or renewal.

4 During any interval of planning, it is tolerable to use up a fraction of any soil property (such as depth) that is present in excess of present or predictable future needs.

5 Tolerance is independent of economic influences, but methods of keeping erosion within tolerance are likely to be determined by economic returns.

Then, three decisions must be made:

1 A decision on the essential soil properties to use as the basis for erosion tolerance.

2 A decision on the measures of these soil properties needed for the future.

3 A decision on the estimated renewal rate of each soil property considered.

These decisions complete the preparation for calculation of sample erosion tolerances at point p.

- *Instance One*

Assume that the only essential soil property to be considered is depth of material favorable for plant roots (decision one) and that the depth judged necessary for the future is 5 feet (decision two). Suppose, moreover, that we are confident only that renewal of depth is rapid enough to balance geologic erosion (decision three), which may be estimated from data secured from runoff-erosion plots with permanent cover as 500 pounds per acre annually. Finally, suppose that the present measure of favorable depth is known to equal the future requirement. In this case, erosion tolerance at p equals the estimated rate of geologic erosion, i.e., 500 pounds per acre, or 0.00014[1] foot of depth annually.

- *Instance Two*

Assume that a soil with a future depth requirement of 5 feet has a present depth that exceeds the needed future depth by 5 feet. The erosion tolerance in this case would include fractional use of the 5 foot reserve depth during any interval of planning. Thus, for 1,000 years the average annual soil-loss tolerance can be (0.00014 + 0.005 foot =) 0.00514 foot, or 9.3 tons per acre.

- *Instance Three*

Assume a 5-foot future need and a present measure of soil depth favorable for plant roots of 4.5 feet. Since present soil depth is 0.5 foot less than needed, the basic conservation problem in this case is development of greater depth to satisfy future needs. Here, the "net change tolerance" is negative, and a negative rate of change can be set by choosing a date for achieving the full 5 feet of favorable depth needed for the future. Defining the future as 1,000 years hence, the required annual rate of change is 0.0005 foot, or 0.9 ton per acre, which must be added to the present depth to achieve the conservation goal. This means that annual erosion tolerance equals the soil renewal rate minus 0.9 ton per acre.

The steps outlined have led to the establishment of tolerance standards at point p. Since p is any point on the landscape, the procedure described can be used in expanded form to establish erosion tolerance levels for an area of any size, a field, a farm or a larger region. This implies that

[1]Based on an assumed weight of 150 tons per acre inch of soil.

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critical points in gullies or on shallow soil or steep slopes will be included. In certain cases, especially on dominantly deep soils, confining erosion to tolerable limits at critical points is the most appropriate test of a conservation plan.

The several assumptions and decisions on which the procedure for establishing erosion tolerances is based are explained in detail in the material that follows.

The first assumption is a statement of principle that for some time has been accepted as implied public policy in the United States; it is based on a legislative act which states in part: ". . . that it is hereby declared to be the policy of Congress to provide permanently for the control and prevention of soil erosion . . ."[2]

Assumptions two and three are definitions which serve to provide needed terminology, while assumption four prevents violation of tolerance by placing minimum restrictions on the use of reserves.

Assumption five was made after considering the alternatives of either including economic influences or of ruling them out. If included, then tolerance standards must be expressed as some function of prices and costs as well as of noneconomic influences. Moreover, since complex price-cost variations are normal in any competitive society, erosion tolerance standards based partly on economic variables are likely to fluctuate, in some cases rather widely, even though essential soil characteristics are being maintained or improved.

Exclusion of economic influences eliminates some complex variables, aids simplification of the procedure, and maintains unqualified identity of erosion tolerance standards with the principle stated in assumption one. At the same time, it places no arbitrary restrictions on land use or management, but merely sets bounds within which choices must be made, without regard to the economic consequences of such choices.

Thus, we concluded that both technical precision and practical usefulness were increased by excluding economic variables from any basic erosion tolerance calculation and that at the same time such exclusion emphasized the importance of selecting economic alternatives within the limits of erosion tolerance.

The three decisions that must be made in using the procedure for determining erosion tolerances involve a variety of considerations. The first decision is technical and can be made best by people familiar with a particular soil. There would probably be general agreement among soil scientists regarding the most important soil properties lost through erosion. In some cases, especially with water erosion, depth of favorable material might be the main essential property to consider. In other cases, deterioration of essential texture, structure, or fertility characteristics might have to be expressed and accounted for in the erosion tolerance determination.

Decision two is partly technical and partly a matter of public policy. Established conservation policy would prevent acceptance of soil property measures that are inadequate for sustained maintenance or improvement of soil productivity.

Soil-forming processes and geologic erosion may have held the depth of virgin soil below that which will be needed, but there is no reason to accept this depth deficiency as tolerable for all time. It is just as logical to plan longtime improvements in soil depth as to plan to remedy plant nutrient deficiencies, even though it may be more difficult to surmount the technical problems involved.

With present crops and climate, sufficient depth for normal crop rooting might be used as an acceptable general standard of future need for depth. Also, considerable information is available on which to base standards for other soil properties. Additional research should, in time, add to the precision of these property measurements.

Decision three is largely technical, and basic information is often inadequate for definite conclusions. Where underlying rock is resistant to weathering and the influx of wind- and water-borne sediment is small, the only safe judgment may be that the unmodified renewal rate is slow.

In considering a mature soil, it is reasonable to assume that the geologic erosion rate and the renewal rate are equal.

With favorable underlying material, such as windblown silt, the soil's renewal rate from below may be extremely rapid. In contrast, a crystalline limestone with a 10 percent impurity of silt and clay and a maximum weathering rate of 1 inch in 240 years (*2*) would provide a maximum residue of only 250 pounds per acre annually for soil renewal.

[2]Public Law 46, 74th Congress, April 27, 1935. Also, U. S. Department of Agriculture, Secretary's Memo 1488, February 1, 1962.

Each point of the landscape complex requires attention in determining erosion tolerances. ***SCS Photo***

The paucity of data on the subject is evidence that soil renewal has received little attention compared to erosion, although solution of basic soil conservation problems depends at least as much on soil renewal as on control of erosion.

Summary

The procedure to establish an erosion tolerance standard at any point requires assumptions: (a) that soil is to be preserved or improved, (b) that various soil properties are subject to both wearing away by erosion and adding to by renewal, (c) that all kinds of erosion and renewal are involved, (d) that fractional using-up of reserves is tolerable, (e) that economic influences determine choices within tolerance, but not the tolerance, itself.

Also, decisions must be made as to the identification of soil properties upon which to base erosion tolerance standards, the measures of these properties that are needed for the future, and assured rates of soil property renewal.

These assumptions and decisions provide a logical, consistent basis for establishing an erosion tolerance or net change tolerance at any point. Moreover, by checking critical points and typical cases, it is possible to extrapolate erosion tolerances over a farm or larger region.

The precision of any established erosion tolerance standard depends upon the soundness of the three decisions, which are determined partly by public policy and partly by technical facts or estimates.

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